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Effect of plant growth regulators and fertilizers on growth and economics of sunflower (*Helianthus annuus* L.)

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Abstract
A field Experiment was laid out during Zaid 2021 at Central Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P.). The soil of experimental plot was sandy loam in texture, It is nearly neutral in soil reaction (pH 7.2), low in organic carbon (0.58%), available N (238 kg/ha), available P (32.10 kg/ha) and available K (189 kg/ha). The treatment consists of 4 levels of GA_3 (100ppm), GA_3 (200ppm), Ethrel (250 ppm), Ethrel (500 ppm) and 2 levels of fertilization (NPK) 80:40:40, (NPK) 100:50:50 whose effect was observed on sunflower. There were Nine treatments each replicated thrice. The experiment was conducted in Randomized Block Design. The results showed that growth parameters *viz*. Plant height (128.60cm) at 80 DAS, No of leaves per plant (22.93 g) at 60 DAS and crop growth rate (2.24) at 60 DAS in (NPK 100:50:50 + GA_3 200 ppm). The Yield parameters *viz*. Number of seeds per capitulum (370.00), Test weight (38.60), seed yield (1480 kg/ha), stover yield (2903.20 kg/ha), biological yield (4383.20 kg/ha), Gross returns (162800 ₹/ha), Net returns (128252 ₹/ha) and BC ratio (1.26) were recorded maximum with application of (NPK 100:50:50 + GA_3 200 ppm). Number of unfilled seeds per capitulum (21.63) were recorded maximum with application (NPK 80:40:40 + $GA_3$100 ppm) and Harvest index (52.63%) were records maximum with application in (NPK 80:40:40 + GA_3 200 ppm).

Keywords: Sunflower, nitrogen, phosphorus, potassium, GA_3, Ethrel

Introduction
Sunflower (*Helianthus annuus* L.) is one of the fastest growing and important vegetable oilseed crops in the world, native to southern parts of United States of America and Mexico and ranks 4th next to groundnut, soybean and rapeseed. In Greek "Helios" means sun and "Anthos" means flower, popularly known as-Surajmukhi or-Sooryakanthi belonging to the family Asteraceae. The name is just for a plant that turns its flower to face directly into the sun as it passes and also looks like the sun in its yellow rays. Oilseed crops occupy an important position next to food grains in Indian economy. The oil not only forms an essential part in human diet but also serves as an important raw material for manufacture of Different products like flavour enhancers, lubricants etc. Sunflower crop was introduced to India during 1969 as a supplement to traditional oilseed crops to bridge the gap of recurring edible oil shortage in the country. The commercial cultivation of sunflower started in India during 1972-1973 with an introduction of Russian varieties from USSR and Canada. Now, the crop is well adopted because of its desirable attributes such as short duration, photoperiod insensitivity, adoptability to wide range of soil and climatic conditions, drought tolerance, higher seed multiplication ratio (1:50) and high quality of edible oil (45-50%), which contains polyunsaturated fatty acid (PUFA). India produces 1.44 million ton (mt) of total sunflower seeds from an area of about 2.34 million ha, with an average productivity of 615 kg ha^{-1} (Shekhawat and Shivay, 2008) [24]. Since introduction of this crop in India productivity has remained low as compared to world average productivity through the area under this crop has increased markedly. Optimum resources use efficiency (RUE) is a prerequisite for sustainable production system. A major driver for field especially in intensive agricultural systems, is fertilizer. Inappropriate use of fertilizers in sunflower, particularly excessive or ill-timed application, can lead to poor uptake, wasted valuable resources, and potential environmental damage (Hawkesford, 2012) [10].
Sunflower (*Helianthus annuus* L.) is a temperate zone crop but it can execute well under varying climatic and soil conditions. In world it is cultivated on area of 18.12 million hectares with an annual production and profitability of 22.03 million tonnes and 1216 kg per hectare, independently (Annonimus 2014-2015). Sunflower (*Helianthus annuus* L.) is one of the most

preeminent oilseed crops in India, grown in an area of 0.55M ha. with a production of 0.42M.T. and profitability of 758 kg ha-1, respectively (Annonimus 2014-2015). The cultivation of sunflower is largely confined to southern parts of the country comprising the states of Karnataka, Maharashtra, Tamil Nādu and Andhra Pradesh. These four states contribute about 9% of total acreage and 78% of total production. Maharashtra ranks second in area as well as production after Karnataka. In Maharashtra, sunflower is grown on an area of 0.05 M ha. with the production of 0.02 M. T. and having potency of 459 kg ha-1 (Annonimus 2014-2015). Nitrogen (N) is the most remarkable nutrient to enhance yield and quality of sunflower seeds. It is an essential plant nutrient to stimulate plant growth and development and ultimately yield and quality (Ullah *et al*., 2010) [26]. Fertilizer needs of common sunflower cultivars differ based on ecological conditions annual precipitations, irrigation regimes and plant species. Excessive N amount enhance photosynthesis process, increase leaf area and net digestion rates (Munir *et al*., 2007) [19]. Therefore, actual nitrogen doses should be so choose as to improve yield and quality but to prevent negative impacts on human and soil health. With the advancement of crop profitability through the acquiring of high yielding varieties and multiple cropping systems, fertilizer use has become progressively important to increase crops yield and quality. Among nutrients, nitrogen plays an vital role in growth and yield of sunflower (Khaliq and Cheema, 2005) [11]. Sunflower, crop is a photo and thermo-insensitive crop. During monsoon season, loss of N is quite obvious hence its rational application at right stages of crop growth is desired for higher productivity. Effects of N fertilization on sunflower yield and quality have come under scientific scrutiny because N is a crucial nutrient for plants and it increases total biomass production, yield and its elements. Phosphorus is obligatory to increase oil content and potash helps to grain filling and disease resistant. The micronutrients play an important role in cell division, cell elongation and regulation of nutrients from one part to other part of the plant. Micronutrient malnutrition now afflicts over 40% of the world's population and is increasing particularly in many developing countries.

Nutrient requirement of hybrid sunflower is high and the crop is characterized by high plasticity under different nutrient availability. High rate of N, P and K is used to produce one ton of seed (Bhattacharyya *et al*. 2014) [5]. The glaring non-responsiveness to application of recommended or elevated levels of NPK is due to growing hidden hunger. There is general agreement on the nature of the reaction of sunflower to variations in NPK supply, but little emphasis has been placed on documenting the combined effect of levels of nutrients in different combinations under varied irrigations stages to achieve sustainable hybrid sunflower productivity, under-or over-supply of irrigation water may affect growth, seed yield and oil quality of crop. Nitrogen (N) deficiency is frequently a vital limiting factor for crops production in over the world. The plays vital role of nitrogen in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances of every cell. In addition, nitrogen is also found in chlorophyll that enables the plant to transfer of energy from sunlight by photosynthesis. Thus, nitrogen supply to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Moreover, it impacts cell size, leaf area and photosynthetic activity. Therefore, adequate supply of nitrogen is required to attain high yield potential in crops.

Plant growth regulators (PGRs) have the capacity to alter every phase of plant growth spanning from seed germination to crop maturity. Since most plant growth and seed development processes are regulated by natural plant hormones, many of these processes might be manipulated either by altering the endogenous hormone level or by changing the capacity of the plant to respond to its natural hormone. It is familiar that plant hormones are involved in grain filling and seed development. (Al-Jobori, 2012). Among these, gibberellins (GAs) are essential endogenous hormones present in plant development by regulating several physiological mechanisms (Hooley, 1994) [22]. Gas can stimulate stem and root elongation, flowering, fruit senescence, seed germination or dormancy (Hedden, 2015). When the gibberellins-based products became commercially available, the astonishing results obtained from their application to many crops raised great expectations of consistently increasing plant productivity. Gas have been commercially applied to control the vegetative growth of many crops. They might expansion of seed yield in firm-headed lettuce, the implementation of exogenous gibberellic acid (GA_3) has gained a renewed effectiveness with the aim to promote plant growth, better yield and increase tolerance to abiotic stresses. Gibberellins and Ethrel may plays vital role in many metabolic pathways influencing these characteristics, such as chlorophyll producing and humiliation, translocation of assimilates, nitrogen metabolism, and nitrogen redistribution. Whereas Ethrel improves the marginal improvement in the vegetation growth.

Nitrogen is the vital nutrient that increases the metabolic processes that lead to increase in vegetative, reproductive growth and yield of the crop. Further Nitrogen fertilizer application influence dry matter production as well as N accumulation and separate into several parts of crop plants for the growth, development and other procedure. Phosphorus deficiencies can maximum the accumulation of crop biomass (Abbadi and Gerendas 2011) [1], observed reduction in the rate of leaf expansion and photosynthetic rate per unit of leaf area of sunflower under P deficiencies. Implementation of K fertilizer was found to be especially effective with respect to yield formation in sunflower (Amanullah and Khan, 2011) [3].

Materials and Methods

An experiment was conducted during the *Zaid* 2021, at Crop Research Farm of Department of Agronomy at Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Prayagraj which is found at 25º 24'42" N latitude, 810 50' 56" E longitude and 98 m altitude above the mean sea level (MSL), The experiment was Conducted in Randomized Block Design with Nine treatments which was replicated thrice. The treatment combination has two factors. The primary factor comprises of two levels GA_3, GA_3-100ppm and GA_3-200ppm and two levels of Ethrel-250 ppm and Ethrel-500 ppm while the second factor has two levels of fertilizers (NPK) Factor 1-80:40:40 and Factor 2-100:50:50. The treatment combination are as following (T1) NPK 80:40:40 + $GA_3$100 ppm, (T2) NPK 80:40:40 + GA_3 200 ppm, (T3) NPK 80:40:40 + Ethrel 250 ppm, (T4) NPK 80:40:40 + Ethrel 500 ppm,(T5) NPK 100:50:50 + GA_3 100 ppm, (T6) NPK 100:50:50 + GA_3 200 ppm, (T7) NPK 100:50:50 + Ethrel 250 ppm, (T8) NPK 100:50:50 + Ethrel 500 ppm (T9)-Control. The DRSH-1 variety of Sunflower was sown with seed rate of 1.3 kg/ha at spacing of 40cm x 30cm.The recommended dose of fertilizer (80:40:40 NPK kg/ha).

Chemical analysis

Composite soil samples are collected before layout of the experiment to determine the initial soil properties. The soil samples were accumulated from 0-15 cm depth and were dried under shade, powdered with wooden pestle and mortar, passed through 2 mm sieve and were analysed for organic carbon by rapid titration method by Nelson (1975) [20]. Obtainable nitrogen was evaluated by alkaline permanganate procedure by Subbiah and Asija (1956) [25], obtainable phosphorus by Olsen's method. Obtainable potassium was determined by using the flame photometer normal ammonium acetate solution and estimating by using flame photometer (ELICO Model) as outlined by Jackson (1973) [16] and available $ZnSO_4$ was estimated by Atomic Absorption Spectrophotometer method as outlined by Lindsay and Norvell (1978) [17].

Statistical analysis

The data recorded for different parameters were subjected to statistical analysis by embracing Fishers procedure of analysis of variance (ANOVA) as described by Gomez and Gomez (2010). Critical difference (CD) values were calculated the 'F' test was found significantly at 5% level.

Result and Discussion

Growth parameters

Observations regarding the plant height (cm) of Sunflower were given in Table 1 and it clearly depicts an increasing trend in plant height during crop growing period from 20 DAS to 80 DAS. At 80 DAS significantly higher plant height was observed in treatment with the application of NPK 100:50:50 + GA_3 200 ppm (128.60cm) in which is statistically at par to NPK 80:40:40 + Ethrel 500 ppm (125.63cm), NPK 100:50:50 + GA_3 100 ppm (127.73cm), NPK 100:50:50 + Ethrel 250 ppm (125.3cm) and NPK 100:50:50 + Ethrel 500 ppm (124.36cm). Increase in plant height might be Due to foliar application of gibberellic acid the increase in plant height can be attributed to the initiation of increased cell division and cell elongation. The promotive result of gibberellins on extension may be enlarge by auxin level of tissue or enhancing the conversion of tryptophan to IAA, which causes cell division and cell elongation, Dhaduk *et al.* (2007) [9]. These findings were found similar to that of Amit kumar *et al.* (2012) [4], Cechin and Fumis (2004) [8], given that there were significant differences between NPK rates 120:60:60 kg/ha and higher rates in terms of the plant height, seed yield, head diameter and oil yield under irrigated conditions of the sunflower. Sadiq *et al.* (2000) [14].

In the present investigation, Number of leaves per plant At 60 DAS, the treatment NPK 100:50:50 + GA_3 200 ppm has recorded significantly highest no. of leaves/plant (22.93), at 80 DAS, NPK 100:50:50 + GA_3 200 ppm significantly highest number of leaves/plant (22.40) which is statistically at par to NPK 100:50:50 + Ethrel 250 ppm (21.77) and NPK 100:50:50 + GA_3 100 ppm (21.73). The increase in number of leaves with the application of gibberellic acid was a result enhanced induction of leaf initial breaks i.e. differentiation of leaf primordial in the apical growing region Pal *et al.* (1986) [13]. Longer stem posses more number of nodes, which in turn results in more number of leaves. Cechin and Fumis (2004) [8]; and Amit kumar *et al.* (2012) [4].

Observations regarding the dry weight are in table 1 and there was dry weight (g/plant) had consecutively increased from 20 DAS to 80 DAS. At 80 DAS the highest dry weight was observed with the application of NPK 100:50:50 + GA_3 100 ppm (11.45 g/plant) and the lowest dry weight was observed with Application of NPK 80:40:40 + Ethrel250 ppm (10.16 g/plant).

Observations regarding the Leaf area index are given in table 1 and there was Leaf area index had consecutively increased from 20 DAS to 60 DAS and slight reduction from 60DAS to 80DAS, At 60 DAS the highest value were recorded with the application of NPK 100:50:50 + GA_3 100 ppm (4.40) and the lowest value recorded with the application of NPK 80:40:40 + Ethrel 250 ppm (4.03) this might due to better available N-growth plants were significantly higher compared to less available N-grown plants. Longer stem poses more number of nodes, which in turn results in more number of leaves. The higher of leaves is reflected in case of leaf area index at all the crop growth period. Cechin and Fumis (2004) [8] and Amit kumar *et al.* (2012) [4].

Observations regarding the Crop growth rate are given in table 1, At 60 DAS NPK 100:50:50 + GA_3 200 ppm significantly highest crop growth rate (2.24 g/m^2/day) which is statistically at par with the application of NPK 80:40:40 + $GA_3$100 ppm(2.03 g/m^2/day), NPK 80:40:40 + GA_3 200 ppm(1.91 g/m^2/day), NPK 80:40:40 + Ethrel 250 ppm(2.12 g/m^2/day), NPK 100:50:50 + GA_3 100 ppm(2.09 g/m^2/day) and NPK 100:50:50 + Ethrel 500 ppm(2.16 g/m^2/day) due to the higher availability of N and P in the initial stage, which helped to acquire a definite advantage over control in respect of growth Mishra *et al.* (2010) [12] shortage of N affects the development and growth of both source and sink, Cantagallo *et al.* (2009) [7].

Economics

The maximum Gross returns and net return was found with the application of NPK 80:40:40 + GA_3 200 ppm (162800.00 INR/ha) and (128252.00 INR/ha). And the lowest Gross returns was observed with the application of NPK 80:40:40 + $GA_3$100 ppm (146813.33 INR/ha), lowest Net returns was observed with the application of NPK 100:50:50 + Ethrel500 ppm (114448.67 INR/ha). Higher B:C ratio was found in with the application of NPK 100:50:50 + Ethrel500 ppm (1.30). The lowest was observed with the application of NPK 100:50:50 + GA_3 100 ppm (1.266).

The enhancement in the NAR was accredited due to maximum vegetative growth as explained by Abelardo & Hall (2002) [2] that was higher as in response with the application of nitrogen fertilizer.

Shahi *et al.* (2012) [13] explained that the experimental data revealed that the application of sources of nutrients in different combination, recorded the cost of cultivation 20754.35 Rs. ha, highest net return 23200.15 Rs. ha, gross return 43954.50 Rs. ha and B:C ratio value 2.12 was obtained treatment receiving application of NPK (100:50:50 kg + GA_3 200ppm) Bandur *et al.* (2000) [6] given during the experimentation, application of nutrients N_{80} P_{40} and K_{40} residual effect of sunflower stover incorporation recorded the maximum gross return (56.56*10^3 INR/ha), net return (41.82*10^3 INR/ha) and B:C ratio (2.86). This may be attributed due to buildup of soil fertility and productivity over the time due to sunflower stover incorporation. Mangare *et al.* (2008) [18] reported that the residual effect of 30kg P/ha produced the maximum gross return (59.20*10^3 INR/ha), net return (44.46*10^3 INR/ha) and B:C ratio (3.00) this could be ascribed to the fact that substantial fraction of P applied was utilized by succeeding sunflower crop resulted in improvement in yield of sunflower without any increment in cost of cultivation, which consequently reflected in gross return, net return and B:C ratio accrued from sunflower crop. Oyinlola *et al.* (2010) [21] had shown that head diameter of sunflower increased with the increases in nitrogen rate. Indeed, this effect was expected because of positive contribution of nitrogen on no of filled seeds. Due to this, efficient and greater partitioning of metabolites and adequate translocation of nutrients. Nitrogen fertilizer increased economic yields of sunflower.

Table 1: Effect of plant growth regulators and fertilizers on Growth attributes of sunflower

Treatments	Plant height(cm)				No of Leaves/Plant				Plant dry weight (g/plant)				Leaf area index				Crop Growth rate(g/m^2/day)			
	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS	20 DAS	40 DAS	60 DAS	80 DAS
T_1 – NPK 80:40:40 + $GA_3$100 ppm	7.71	46.67	79.67	121.07	8.70	16.04	20.63	20.57	0.42	6.73	9.71	10.71	0.37	2.58	4.17	2.77	0.45	3.02	2.03	1.65
T_2 – NPK 80:40:40 + GA_3 200 ppm	7.60	48.70	78.57	120.97	8.57	16.20	20.23	20.30	0.41	6.94	9.74	10.91	0.36	2.54	4.12	2.81	0.44	3.05	1.91	1.15
T_3 – NPK 80:40:40 + Ethrel250 ppm	7.20	47.69	78.73	121.10	8.43	16.03	20.13	20.23	0.43	7.08	9.24	10.16	0.38	2.70	4.03	2.72	0.45	3.12	2.12	1.70
T_4 – NPK 80:40:40 + Ethrel500 ppm	7.73	48.20	80.33	125.63	8.77	16.93	20.97	21.07	0.46	7.37	9.45	10.55	0.41	2.84	4.11	2.76	0.46	3.16	1.89	1.47
T_5 – NPK 100:50:50 + GA_3 100 ppm	7.87	51.23	83.50	127.70	8.90	17.20	21.73	21.73	0.42	7.40	10.31	11.45	0.42	2.88	4.40	2.95	0.49	3.15	2.09	1.74
T_6 – NPK 100:50:50 + GA_3 200 ppm	8.10	51.70	84.80	128.60	9.53	17.57	22.93	22.40	0.45	7.84	1087	11.23	0.42	3.22	4.23	3.08	0.47	3.35	2.24	1.73
T_7 – NPK 100:50:50 + Ethrel250 ppm	7.63	47.67	81.07	125.13	8.58	16.63	21.37	21.77	0.43	7.39	10.04	10.47	0.39	2.98	4.21	2.84	0.46	3.15	1.85	1.68
T_8 – NPK 100:50:50 + Ethrel500 ppm	7.57	48.27	82.43	124.63	8.57	16.87	21.03	20.97	0.45	7.44	10.17	10.54	0.40	2.97	4.06	2.74	0.44	3.12	2.16	1.66
T_9 – Control	7.03	45.07	79.13	120.03	8.03	15.97	19.73	19.33	0.40	6.26	9.26	9.92	0.34	2.20	3.80	2.32	0.42	2.95	1.67	1.39
S.Em (±)	0.16	1.23	1.23	1.35	0.17	0.19	0.38	0.33	0.02	0.32	0.39	0.54	0.02	0.35	0.30	0.33	0.03	0.13	0.11	0.05
CD (0.05%)	0.48	3.68	3.70	4.04	0.51	0.57	1.14	1.00	0.07	0.94	1.17	1.62	0.07	1.04	0.89	1.80	0.09	0.38	0.33	0.14

Table 2: Effect of Plant Growth Regulators and Fertilizers on Economics of Sunflower

Treatments	Cost of cultivation (INR ha^{-1})	Gross returns (INR ha^{-1})	Net returns (INR ha^{-1})	B:C Ratio
T_1 – NPK 80:40:40 + $GA_3$100 ppm	32006	146813.33	114807.33	1.279
T_2 – NPK 80:40:40 + GA_3 200 ppm	32756	152826.67	120070.67	1.272
T_3 – NPK 80:40:40 + Ethrel250 ppm	32106	151506.67	119400.67	1.269
T_4 – NPK 80:40:40 + Ethrel500 ppm	32956	154513.33	121557.33	1.271
T_5 – NPK 100:50:50 + GA_3 100 ppm	33798	160416.67	126618.67	1.266
T_6 – NPK 100:50:50 + GA_3 200 ppm	34548	162800.00	128252.00	1.269
T_7 – NPK 100:50:50 + Ethrel250 ppm	33898	153156.67	119258.67	1.284
T_8 – NPK 100:50:50 + Ethrel500 ppm	34748	149196.67	114448.67	1.303
T_9 – Control	23950	140396.67	116446.67	1.205

Conclusion

On the basis of one season experimentation the application of NPK 100:50:50 kg/ha + Gibberellic acid 200 ppm was recorded higher Seed yield (1480 kg/ha) as well as with greater (B:C ratio) Since the findings were based on the research done in one season it may be repeated for further confirmation and recommendation.

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